

# COASTAL HERITAGE

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## The Global Plastic Breakdown *How Microplastics Are Shredding Ocean Health*





# CONTENTS

3

## THE GLOBAL PLASTIC BREAKDOWN: HOW MICROPLASTICS ARE SHREDDING OCEAN HEALTH

*What's happening to sea life as plastics are shredded into smaller and smaller pieces?*

5

## TINY PARTICLES, BIG PROBLEMS

*Smaller particles are especially "sticky," capturing waterborne contaminants.*

12

## SWEEPS CAPTURE PLASTIC LITTER, INCLUDING CIGARETTE BUTTS

*Cigarette butts are primarily made from plastic. Dispose of them properly.*

14

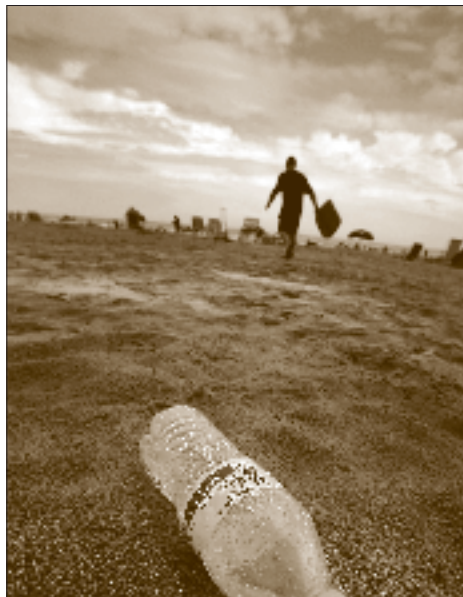
## NEWS AND NOTES

- New insights on marketable clams
- Accountant/fiscal analyst joins Consortium
  - Litter cleanup volunteers needed
- Coastal Heritage wins prestigious awards

16

## EBBS AND FLOWS

- 26<sup>th</sup> Annual Beach Sweep/River Sweep
- 2014 S.C. Water Resources Conference
- 16<sup>th</sup> International Conference on Shellfish Restoration



### ON THE COVER:

*On the beach, sunlight and surf will break up plastic bottles and cups  
into tiny pieces that can't be seen with the naked eye.*

PHOTO/GRACE BEAHM



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**PLASTIC FOOD.** John Weinstein, a biologist at The Citadel, notes that plastic items trapped in salt marshes will eventually deteriorate into particles that can endanger the health of tiny grazing animals.

PHOTO/GRACE BEAHM

# The Global Plastic Breakdown

## *How Microplastics Are Shredding Ocean Health*

by John H. Tibbetts

**O**ops! The wind on the beach just snatched a plastic bag out of your hand and now it's cartwheeling down the shoreline faster than you can run after it. Look at that thing go. The wind catches it like a kite. It swoops high over the surf and then dives into the sea. You feel guilty, of course, for littering. But maybe the bag will later wash up on shore and somebody will put it in a trash bin.

It's more likely, though, that your plastic bag will be shredded to bits. On the sea surface, ultraviolet radiation in sunlight makes plastic brittle, and heat and wave action shear it off in flakes. Over time, the flakes are shredded further by the elements,

becoming smaller and smaller and smaller—until they can become food particles for tiny organisms.

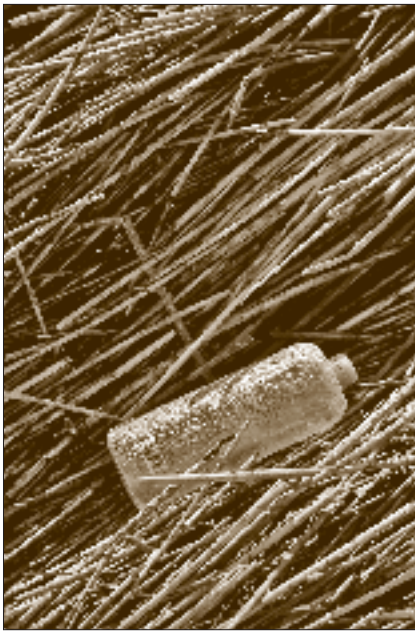
Some plastic flakes drift like snow down the water column where fish can consume them. Other bits fall farther to the muddy bottom where they are gobbled up by grass shrimp and other creatures. Still other plastic pieces wash up onto beaches and salt marshes where they become food for burrowing worms and filter-feeding oysters.

But maybe your plastic bag remains intact and washes up on a beach or a salt marsh. The same weathering processes will degrade it there. Plastic breaks up far faster on a

hot, bright, abrasive place like a salt marsh or beach than it does in colder, deeper water.

"If you have a plastic bottle that's sitting up in the marsh," says S.C. Sea Grant researcher John Weinstein, a biologist at The Citadel, "it's going to fragment from sunlight and wave action. It may take a long time, but someday that bottle will disappear from view. Its fragments, though, will still be there, and they will get smaller until they become particles. The plastic will still be in the environment. It just won't be of a size that we can see. But it could be the right size for organisms in the salt marsh that ordinarily feed on bits of detritus or





**UBIQUITOUS.** A plastic bottle found on salt-marsh “wrack,” or decomposing stems.

PHOTO/GRACE BEAHM

other particles. My analogy is that we’re sweeping these plastics under the rug. We can’t see them anymore, but they’re still there.”

Many animals, of course, can suffocate on plastic bags after ingesting them. Sea turtles, for instance, mistake plastic bags for jellyfish. Albatrosses mistake red plastic pieces for squid; photos of bird corpses show dozens of red bottle caps in their decayed guts. Plastics can block or abrade animals’ guts, so they can’t get adequate nutrition and they starve. Other animals lose the energy to search for food, fend off predators, or reproduce.

Now scientists are finding compelling evidence that tiny bits of plastic in the ocean can be just as dangerous for small marine life.

The National Oceanic and Atmospheric Administration (NOAA) defines microplastics as pieces smaller than 5 millimeters in diameter, or about the diameter of a pencil eraser. But many scientists, including Weinstein, define microplastics as items smaller than 1 millimeter, which is also the upper size limit of plankton and detritus particles that

many aquatic organisms consume as food.

Microplastics have shown up in the guts of mussels, barnacles, worms, fish, and many other creatures. In a series of experiments, Richard Thompson, at biologist at Plymouth University in Britain, added plastic particles and fibers to the diet of three different bottom-feeding creatures: lugworms, barnacles, and sand fleas. The animals consumed the plastic items. The plastic items passed through the guts of some individuals. But others were not so lucky; the particles blocked up their guts and killed them.

John Weinstein is studying how grass shrimp (*Palaemonetes pugio*) respond to a diet of plastic beads. A crustacean about the size of half of a shelled peanut, a grass shrimp consumes microalgae that grow on plant detritus—especially decomposing saltmarsh stems called “wrack”—along estuaries and coasts, but it’s also a predator on a wide variety of small animals.

Because of its abundance, sensitivity, and ecological importance in southeastern U.S. estuaries, the grass shrimp is often used to study the effects of pollution in the field and laboratory.

In Weinstein’s lab, Austin Gray, a graduate student in biology at The Citadel, has been feeding grass shrimp two types of beads: one a bright green and the other one translucent.

The green beads are polyethylene, the type of plastic used in plastic bags, bottles, plastic wrap and other films for food preservation, and many other products. Polyethylene is the most common type of plastic found in marine debris around the world.

The translucent beads are polypropylene, a type of plastic used in bottle caps, candy- or chip-wrappers, and food containers. Polypropylene is the second most common type of plastic found in marine debris.

In a lab dish, Austin Gray deposits its translucent 75-micron beads. But a visitor looks in the dish and can’t find

a single bead. Under the dissecting microscope, though, dozens of tiny spheres suddenly appear. To put it in perspective, an item at about 40 microns is the width of two spooning human hairs.

Gray fed 16 grass shrimp a diet of brine shrimp mixed in with plastic beads. Each grass shrimp was isolated in water that was changed every other day. Eight animals were fed polyethylene beads and eight were fed polypropylene beads. After six days, all of the 16 shrimp were dead.

Dissecting the animals, Gray found plastic beads in their guts and gills. One individual had 10 tiny beads in its gut and 16 in its gills.

The gut blockages, though, were deadlier. The grass shrimp could still take in water through their partly blocked gills. But they stopped eating with clogged guts—or couldn’t eat—and died.

“In my mind,” says Weinstein, “it’s consistent with starvation. The more particles in guts, the more quickly the grass shrimp die.”

Many plastic particles in the global ocean are probably from ordinary household items that were used once, discarded, and degraded over time into tiny bits.

We dispose of plastic bags, food containers, snack bags, water bottles, bottle caps, and milk cartons. Half of the plastic manufactured today is intended for one-time use.

Plastic is even in our clothing. Yes, nylon and polyester are plastics, too. Synthetic microfibers break off from clothes in household washing machines and slip past wastewater-treatment plants into waterways. One garment can lose 1,900 microfibers in a single washing.

In 2013, undergraduate students under the supervision of Phil Dustan, a biologist at the College of Charleston, reported the discovery of synthetic microfibers in lowcountry oysters, including those in undeveloped Bulls Bay north of Charleston.

Then there are plastic beads used in hundreds of products, including

toothpaste and exfoliating scrubs, finding their way to the sea. A single bottle of facial cleanser can have 350,000 microbeads that wash down the drain and slip through wastewater-treatment plants.

Resin pellets show up, too, on shorelines. Manufacturers melt down raw resin pellets into molds and then shape them into products from plastic toys to automobile components. Resin pellets often spill from plastics-manufacturing sites or from shipping containers.

Each of us encounters hundreds of plastic items in a typical day. First thing in the morning: plastic toilet seat, plastic shower curtain, plastic shampoo bottle, facial cleanser (plastic bottle and perhaps microbeads)—and we haven't even gotten out of the bathroom.

Some disposed items end up in landfills, some in recycling bins, but a good fraction—no one knows how large—becomes litter. Winds blow litter off city streets and beaches into waterways, and storm runoff carries it into drains that empty into waterways pouring to the sea. Sewage treatment captures many larger plastic items from reaching waterways, but small items often still slip through.

Some 60-to-80% of plastic marine debris comes from land sources, including litter and sewage-treatment effluent. Another portion comes from oceangoing vessels.

"We still don't know exactly where microplastics are coming from and where they go," says S.C. Sea Grant researcher Stephen Klaine, an aquatic toxicologist at Clemson University, who is collaborating with Weinstein to study the presence and effects of microplastics and nanoparticles in South Carolina estuaries and how they interact with contaminants.

"The input of microplastics from the rivers into coastal oceans is unmeasured," says Klaine, "but it could be huge. So coming up with true exposure numbers is a major challenge."

Plastics can stay around for a very

long time. They don't biodegrade—not like wood or paper. Microbes disassemble the molecules of, say, a tree branch and recycle its parts back into carbon and water. It took the ocean millions of years to evolve microbes that could efficiently dismantle and reconfigure the molecules of almost anything that washed into it.

Unfortunately, microbes in the ocean haven't evolved to biodegrade huge volumes of plastic items. Plastics, after all, have been produced on a massive scale only since the 1950s, and marine organisms have never experienced anything like them before.

Plastic polymers are very long, carbon-based molecules invented in laboratories. They are designed to be exceptionally tough; they can probably last centuries, or longer. It's likely that nearly all the plastic material that has ever been produced is now buried in landfills, afloat in waterways, or embedded in sediments of oceans and shorelines.

Under a microscope, it's usually easy to separate natural particles from the synthetic ones. The great majority of natural particles on South Carolina beaches are silica—tiny rocks that look like brilliant bits of glass. (Silica is the raw material for glassmaking.) Broken seashells come in many shapes and sizes, of course, but seen through a microscope they appear sturdy and dense in form, resembling shards of pottery.

By contrast, microbeads, perfectly round and uniform in color, are unmistakably the result of high-tech manufacturing. After exposure to sun and pounding surf, polystyrene pieces, popularly known as Styrofoam™, look like squashed popcorn. Other types of microplastic, says Weinstein, resemble thin chips of paint.

Plastic bits in aquatic environments can be magnets for organic pollutants such as polychlorinated biphenyls (PCBs) and the pesticide DDT, which were banned in the U.S. in the 1970s but are still widely found

## Tiny particles, big problems

Smaller particles are more likely to have more extreme chemical reactions to waterborne contaminants than larger particles of the same composition.

The smaller the particle, the higher the percentage of its surface will come into direct contact with contaminants. So the smaller the particle, the likelier its surface will react as a sticky bit of tape, capturing and binding more pollutants to its surface, according to Jamie Lead, director of the SmartState Center for Environmental Nanoscience and Risk at the University of South Carolina.

Consider the surface of a peeled orange.

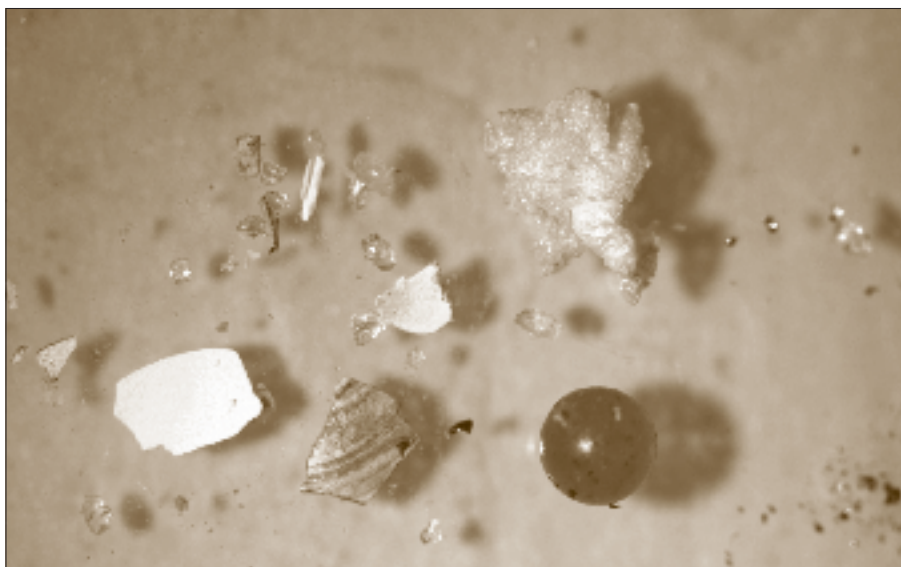
"If you remove segments of the orange," Lead says, "it now has the same mass as before. But the segment areas formerly within the orange have become exposed as new surfaces. For the same mass, the surface area of the orange has increased."

When a material is broken down into smaller and smaller fragments, its surface area increases dramatically.

"Reducing a material to the nano-scale," says Lead, "exponentially increases the surface area available to interact with contaminants. Once divided, the atoms on that now-exposed area are no longer bound to another segment of the orange. They are looking to bind with something else. They are more 'sticky' than when they were within the whole orange."

As plastic items are shredded into smaller and smaller particles in aquatic environments, their new surfaces become more effective in attracting and holding waterborne contaminants.

The shredding process, Lead points out, increases the surface area per unit mass of an item, but it also increases the inherent reactivity of new surfaces, making the materials more likely to take up and bind pollutants. Once bound to particles, pollutants can be more easily taken up by fish and other organisms that people eat. 🍷



**HIGH-TECH PROBLEM.** *A microscopic view of plastic items—microbeads and Styrofoam™—plus broken seashells and grains of sand sampled from a South Carolina beachfront.*

PHOTO/HOPE WERTZ

in marine environments around the world. Both contaminants biomagnify in animals—the contaminants move up marine food chains to higher predators—and both are endocrine disruptors that confuse hormones in animals.

A plastic piece that's buoyant in water quickly attracts and condenses available organic pollutants to its surface. The pollutants usually don't penetrate the plastic. Instead, a plastic piece often functions like a sticky piece of tape, capturing contaminants until they form a concentrated coating.

Hideshige Takada, a geochemist at Tokyo University, tested plastic pellets collected from ocean shorelines on six continents. Pellet surfaces contained concentrations of PCBs 100,000 times-to-1 million times higher than the surrounding water or sediment. The highest concentrations were found in urban estuaries such as Boston Harbor and Ocean Beach in San Francisco. Scientists have worried that when fish and other organisms consumed pellets with highly concentrated contaminants, then the pollutants might build up in animal tissues and enter the marine food chain.

Meanwhile, plastic items are constantly fracturing and shredding on sea surfaces and shorelines, and as they break up, they release cocktails of chemicals into the environment.

Virtually all plastic consumer products are manufactured with various additives. For instance, synthetic fibers used in manufacturing sofas and mattresses have been dosed with flame-retardants to reduce the likelihood of intense household fires. Reinforcing agents, fillers, antimicrobials, and dyes are added to plastic products to make them safer or more convenient to use or more attractive for consumers. Additives such as Bisphenol A (BPA) and phthalates have been shown to leach out of plastics into water and confuse hormone levels in aquatic animals, among other health impacts.

Plastics in the ocean have become globally ubiquitous. Hundreds of aquatic organisms—from invertebrates to many species of fish to whales—consume plastics.

Now, scientists are seeking to untangle the complex interactions among microplastics, the many additives and contaminants they carry or release, and the organisms that try to take nourishment from them.

## LIGHTWEIGHT AND DURABLE

Your car's interior is made mostly of plastic. Dashboard—plastic. Door handles—plastic. Steering wheel—plastic. Now look at your car's exterior. Even the bumpers are made of plastic.

About three decades ago, auto manufacturers began using plastic polymers to replace steel. These polymers were strong, durable, inexpensive, and lightweight. The lighter the vehicle, the less fuel that its engine needed to move it, all other factors considered. So using plastic materials in automobile manufacturing has helped to improve fuel efficiency. The industrial food system also depends on plastic for containers, which are much lighter and thus cheaper to transport than glass containers. Using plastics, then, can help reduce our carbon footprint.

But partly because plastic is so lightweight and durable, it's causing disruptions to the chemical and biological systems in the ocean, especially at the sea surface where countless tiny organisms are searching for buoyant, firm items on which to make their new homes.

Mariners throughout history have contended with colonizing creatures that attach to the bottoms of ocean-going vessels. A thin layer of bacteria will cover a ship's clean hull just three days out of port. This slime—or biofilm—attracts phytoplankton that creates colonies there.

In turn, the larvae of mollusks, tubeworms, and many other animals “foul”—or attach themselves to—the ship's hull. As these organisms mature, they create larger and more complex biological communities that attract even more fouling larvae. Scraping the hull of an average size commercial oceangoing vessel can yield up to 200 tons of organisms.

Today marine bacteria and algae are similarly making new habitats on raft-like surfaces of tiny, buoyant plastic flakes.

Researchers at the Woods Hole Oceanographic Institution and the Sea



Education Association skimmed plastic particles from more than 100 locations in the Atlantic Ocean, from Massachusetts to the Caribbean Sea, bringing up particles coated with fine slimes of colonizing organisms. The scientists identified more than 1,000 different types of bacteria and algae attached to seaborne plastic, according to a report in June 2013 in the journal *Environmental Science & Technology*.

Any effort to strip the sea of tiny plastic pieces and particles—even if this were possible—would also rob the ocean of the bacteria and phytoplankton that form the base of the food web.

Surveys in some industrial coastal regions have shown incredibly high concentrations of plastic bits. One study showed that about 100,000 plastic particles per cubic meter in seawater were found in Swedish coastal waters near a factory that produces polyethylene pellets. To put this into perspective, a cubic meter of water holds 264 gallons, and an Olympic-size swimming pool holds 660,000 gallons.

As those plastics break into smaller and smaller bits, they release their additives while at the same time these plastic particles are attracting other contaminants to their surfaces. Some stretches of the world's oceans have become “chemical soups” in which plastics and their associated contaminants and additives are forming novel combinations.

Microplastics are gathering in vast oceanic gyres covering thousands of miles. Created from intricate networks of ocean currents and wind patterns, these gyres capture and accumulate more and more plastic. The concentrations of plastic debris within these systems can be even higher in hot spots than in polluted estuaries. These gyres of open-ocean chemical soups can't be seen by satellite, making it hard for scientists to measure or track the problem.

Charles Moore, a sailor and oceanographer in California, has been credited with discovering and bringing

public attention to a massive stretch of floating plastic debris in the midst of the North Pacific Gyre in 2003, since named the Great Pacific Garbage Patch. He founded the Algalita Marine Research Institute, which supports sailing expeditions to study plastics in the ocean.

In the Southern Hemisphere, one gyre of plastics sweeps past Easter Island, one of the most remote inhabited islands on the planet, located about 2,500 miles from Hawaii and about 2,400 miles from South America. The island's population is only about 5,700. Yet some of the gyre's seawater samples have almost 400,000 floating plastic pieces per cubic meter, the largest concentrations found yet in the ocean.

But not just micro-size items are floating in ocean gyres. Big things are bobbing along the surface, too, though they will eventually break into smaller ones.

Each year, cargo vessels carry about 100 million shipping containers across the oceans, and some fall overboard and are lost. In the early days of the search after Malaysian Airlines Flight 370 went down in the southern Indian Ocean on March 8, 2014, some floating items were spotted in the area via satellite. Searchers thought that those items were probably parts of the 240-foot-long missing plane. Later, however, searchers concluded that instead they were probably parts of shipping containers lost at sea.

Charles Moore told the Associated Press: “The ocean is like a plastic soup, bulked up with the croutons of these larger items. It's like a toilet bowl that swirls but doesn't flush.”

### THE TRANSFERENCE QUESTION

The ocean is a repository for pollutants that dissolve in seawater or get taken up by algae, by buoyant organic particles, or by bottom sediments.

Scientists know that a small number of very persistent

contaminants can find their way into the tissues of marine organisms and cause illness. Dissolved in seawater, for instance, PCBs and DDT can be drawn through an organism's gills and get transferred to its tissues. Also, these contaminants can be attached to algae, sediments, or food items (including smaller animals), which in turn can be ingested by a marine organism and get transferred through its gut into its tissues.

For years, some scientists suspected that some contaminants associated with plastics might also be reaching marine organisms' tissues, either through guts or gills, but they lacked firm evidence to prove it.

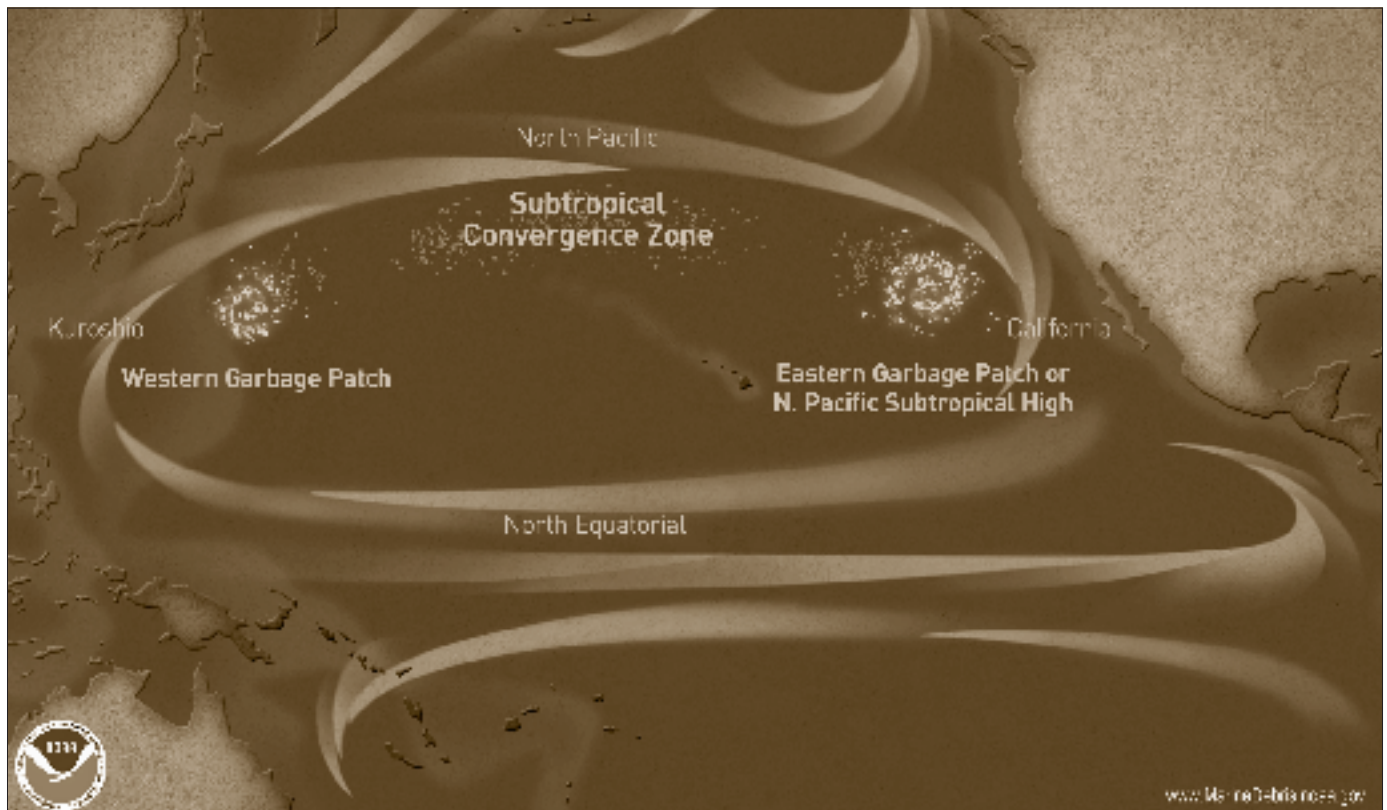
It's been clear for a while that plastic particles are soaking up hazardous chemicals from marine environments and releasing other hazardous chemicals into the sea and sediments.

Yet scientists just could not find conclusive evidence that chemicals associated with plastic directly harmed marine organisms by reaching their tissues.



**ARTIFICIAL HABITAT.** Crabs, barnacles, and sea anemones inhabit a piece of rope debris collected during a Scripps Environmental Accumulation of Plastic Expedition (SEAPLEX) to a Pacific Ocean gyre in 2009.

PHOTO/JIM LEICHTER/SEAPLEX



**Intricate networks of currents and wind patterns create huge ocean gyres that capture and accumulate floating plastic, creating hot spots of plastic particles and chemical contaminants.**

**IMAGE/NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION**

Then Mark Anthony Browne, a British marine ecologist, and his colleagues found their evidence in the lugworm *Arenicola marina*, a reddish-brown invertebrate common to shorelines of the North Atlantic living in burrows on sandy beaches.

A lugworm consumes sandy sediments and digests microorganisms and nutrients while passing the sand particles out as waste through its tail. A lugworm can make up about 30% of the biomass of some shorelines. It's an important source of food for wading birds and flat fish such as flounder. The lugworm's feedings churn sediments in ways that support diverse assemblages of animals there.

Browne designed and carried out laboratory experiments with scientists at Plymouth University in Britain. The researchers exposed lugworms to sand with 5% microplastic that had been coated with chemical additives and pollutants.

Over the 10 days that the animals were fed this diet, the additives and

pollutants from the microplastics did transfer from lugworms' guts to their tissues and continued to accumulate there. The lugworms' tissues absorbed large enough concentrations to reduce their survival, feeding, and immunity, while the ingested plastic itself damaged tissues. These symptoms, in turn, limited the lugworms' capacity to churn sediments, a loss that would likely reduce diversity of organisms on a beach.

"We are putting huge, huge quantities of plastics into the ocean," says Browne, "and we don't know what's happening to them. We're using plastics, additives, and other chemicals, but we're only coming across the problems that they cause much later on, when scientific work is funded. We should be doing experiments to understand impacts before we allow these products on the market."

Other scientists are reporting complementary results.

Chelsea M. Rochman, a marine ecologist/ecotoxicologist at the

University of California, Davis, supplemented the daily diet of fish called Japanese medaka (*Oryzias latipes*) in the laboratory by sprinkling in polyethylene fragments that had been left for three months in nets off a fishing dock in San Diego Bay.

Contaminants such as polycyclic aromatic hydrocarbons (PAHs), PCBs, and flame-retardants from the bay accumulated on the plastic fragments left in nets. Later, in the laboratory, when the fish consumed the fragments, some of the chemicals transferred from their guts to their tissues and accumulated there as well. The fish, in turn, suffered stress in their livers, including tumors.

Another group of fish in her study were fed virgin polyethylene fragments, which also caused liver stress, though less severe.

Marine organisms, she argues, are being exposed to a one-two punch that's new to evolution.

"Plastics are introducing cocktails of additives and ingredients into the



ocean,” says Rochman. “At the same time, plastics are attracting great concentrations of chemicals already present in the environment. The fact that plastics can do both—disperse some contaminants and attract other contaminants—might be unique. A plastic item can be a sink for contaminants but also a source of them. I can’t think of anything else in the ocean that does both.”

Now John Weinstein at The Citadel is finding chemical transfers of fluoranthene, a PAH associated with the combustion of fossil fuels, from water into grass shrimp tissues in his laboratory. Fluoranthene is often found in high concentrations near urban development.

Weinstein coated plastic beads

with fluoranthene and fed them to grass shrimp. The chemical transferred from the animals’ guts to their tissues and accumulated there. Next he fed grass shrimp with tiny brine shrimp larvae, a common laboratory food source for grass shrimp. Then the grass shrimp were moved to water that contained coated pellets but no additional food.

As the grass shrimp passed water through their gills, coated pellets were drawn into the gills as well and became trapped there. From the gills, fluoranthene was transferred to tissues and again accumulated there.

Fluoranthene is acutely toxic to aquatic organisms in far higher doses than are found in South Carolina estuaries.

But when fluoranthene is exposed to UV radiation from sunlight, it becomes an order of magnitude more toxic, and that could be damaging to young, vulnerable animals living in one of the most stressful environments along the South Carolina coast.

Many smaller organisms—juvenile fish, crabs, and shrimp—hide in the harshest areas of the salt marsh to avoid predators. At low tide, they take refuge in sunlit, low-oxygen, high-salinity, shallow waters of headwater tidal creeks near the boundaries of dry upland shorelines. These are the small creeks that mostly dry up at low tide.

“These juveniles at low tide are concentrated in the water left in the creek, which is not very much water at that,” says Fred Holland, former



**PACE OF DETERIORATION.** Brittany Crocker and Daniel Mendez, biology majors at The Citadel, install a device to measure how quickly several different plastic types degrade in a salt marsh. The device’s base is buried in a shallow trench so that strips of plastic types are elevated and exposed to tides and sunlight.

PHOTOS/GRACE BEAHM

director of the NOAA Hollings Marine Laboratory in Charleston. “It’s the time when the juveniles are most vulnerable to predators but it’s also when conditions are most stressful.” Larger predators won’t chase the young, small animals into such shallow water.

At high tide, the young animals escape to higher-elevation fringes of the salt marsh creek banks where predators can’t see them. And at low tide they return to the extremely stressful conditions of headwater creeks where sediments and contaminants such as PAHs settle out on the bottom. This settling of contaminants occurs during slack tide when the water is quiet for a time. “The shallow headwaters are where we find the high levels of contaminants,” says Holland.

Plastic particles tend to be roughly the same size as the sediments that settle out in headwater creeks. It’s likely that plastic particles from the estuary are probably settling out there, too. These particles probably attract and hold PAHs and other contaminants to their surfaces, and the particles become food for juvenile organisms.

“These are already stressful environments for juvenile organisms, but they are adapted to the natural stressors,” says Holland. Not so for microplastics, increased fluoranthene, and other contaminants, “which are going to be added stressors on the animals,” he adds. “You’ll probably see higher mortality rates, slower growth, and other things” because of these multiple exposures.

### **MICROPLASTICS IN BEACH DEBRIS**

On a gorgeous noonday in April, Hope Wertz, a graduate student in marine biology at the College of Charleston, is carefully scraping damp sand from a half-meter transect along the surface of a Sullivan’s Island beach and dropping the sand into a bucket. She’s working at land’s end where the sandy beach and a maritime forest

form the northeastern mouth of Charleston Harbor.

Wertz and two friends—volunteer graduate students—are sampling sediments in an effort to measure and characterize microplastics buried along the shoreline. Wertz plans to sample sediments from three different sites in Charleston Harbor, including this one on Sullivan’s Island, one at Grice Cove on James Island, which forms the southwestern mouth of the estuary, and one on Drum Island, a spoil

island in the harbor.

With guidance from her thesis supervisor John Weinstein, she hopes to learn where microplastics are distributed in four shoreline zones from low-tidal areas up to the oceanfront bases of dunes, as well as along the length of the beach.

Wertz and her volunteers pour ocean water into the bucket of sediments and add more salt. They stir it all up—and wait. Plastic is less dense than seawater, so plastic pieces should



**FROM PLASTIC TO MICROPLASTIC.** Hope Wertz (front), a graduate student in marine biology at the College of Charleston, looks for microplastics on Sullivan’s Island. She is studying whether microplastic samples from Charleston Harbor shorelines are comparable in type and volume to larger plastic items gathered and counted during the 2013 Beach Sweep/River Sweep litter cleanup.

PHOTO/GRACE BEAHM



float to the surface.

From the bucket Wertz pours off water through a series of four sieves from 1 millimeter (1,000 microns) down to 38 microns.

Later, with microscopes, she'll measure and characterize the particles. That will allow her to estimate the volume of the shallow shoreline sediments in Charleston Harbor that are actually plastic particles of less than 1 millimeter.

Although microplastics have been collected and characterized from many U.S. Atlantic Coast beaches, no studies have been done on the South Carolina coast.

"Microplastics haven't been sampled and characterized in any estuary or harbor setting in the U.S.," Wertz says. "I've seen studies in the open ocean, coastal beaches, lakes, and just this year mangroves, but no estuaries or harbors yet. A number of studies have used similar sampling methods. But most have only sampled at one site, or at one tidal height, or along one transect. I'm trying to be as comprehensive as possible."

Wertz plans to compare her samples in the harbor with plastics gathered during the annual Beach Sweep/River Sweep litter cleanup, organized by S.C. Sea Grant Consortium in partnership with S.C. Department of Natural Resources.

Wertz collaborated with seven site captains and student volunteers during Beach Sweep/River Sweep in September 2013, compiling all of the plastic items collected during the one-day cleanup event. The researchers and volunteers counted and weighed each plastic item gathered.

With these data in hand, the researchers extrapolated the volume of visible plastic debris along the entire harbor's shorelines.

"We figured out that there would be one plastic item taken every three steps along the harbor," says Weinstein. "There would be 50 pounds of plastic debris every mile. For the entire harbor shoreline, that turns out to be 15,250 pounds taken



**NEEDY AREA.** Beach Sweep/River Sweep site captain Pam Ferguson (center, in back) and volunteers with the Medical University of South Carolina's Student Government Association pick up debris in 2013 from a marsh area under the James Island connector in Charleston. This location was one of eight sites sampled during Hope Wertz (College of Charleston) and John Weinstein's (The Citadel) study, "Plastic Debris in Charleston Harbor."

PHOTO/BRAD FERGUSON

from the brackish shoreline associated with the harbor."

In their next step, Wertz and Weinstein will follow a similar process for microplastics, measuring their volumes at particular sites in the harbor and extrapolating these data across the entire harbor's shores. The scientists hypothesize that they will find comparable types and volumes of microplastics on shorelines as were found during Beach Sweep/River Sweep. It's likely that most of the microplastics on harbor

shorelines are shredded bits of larger plastic items, not tiny items from facial cleansers or microfibers from clothes.

"This research, I think, will underscore the importance of an event like Beach Sweep/River Sweep," says Weinstein. "If you see a bottle in the marsh and you don't pick it up, it will eventually break up into many microplastics. If you don't collect those larger pieces of plastic trash, they will disappear, and not in a good way." ♡

# Sweeps capture plastic litter, including cigarette butts

Each year along the state's waterways and beaches, South Carolinians and visitors pick up tons of plastic litter items that would otherwise shred into smaller and smaller pieces and potentially threaten aquatic life. Cigarette butts, which few people realize are manufactured with synthetic fabrics, made up the majority—53%—of all marine-debris items gathered and counted during the 2013 Beach Sweep/River Sweep.

Beach Sweep/River Sweep is South Carolina's largest one-day volunteer cleanup event of its kind. Every third Saturday in September, from 9 a.m. to 12 p.m., thousands of dedicated volunteers clear beaches, rivers, lakes, marshes, and swamps of debris.

The cleanup, organized by the S.C. Sea Grant Consortium and the S.C. Department of Natural Resources, has taken place since 1988 when the Consortium first started it.

The Sweep is held in conjunction

with the International Coastal Cleanup, coordinated by the Ocean Conservancy, in which more than 100 countries now take part. Each year, the Ocean Conservancy publishes a detailed inventory of every item of debris that's been collected. This helps track down the sources of litter.

The trash collected around the world shows a surprising uniformity. In beaches from the United States to China to France, volunteers pick up plastic bottles, plates, cups, straws, stirrers, and fast-food wrappers.

The Ocean Conservancy reports that "cigarette butts have been the single most recovered item since collections began."

Most of us wouldn't think of cigarette butts as plastic items. But the vast majority of cigarette filters around the world are made with fibers called cellulose acetate. Manufacturers add a chemical called acetic anhydride to cellulose fibers made from wood or cotton. The resulting chemical

reaction creates thin, very strong fibers. Packed tightly together and chemically designed to absorb vapors and to accumulate smoke particulates, these chemically enhanced fibers provide a rigid, sturdy filter.

Cellulose fibers degrade naturally in the environment. But cellulose fibers manufactured with additives of cellulose acetate are not biodegradable; they shred into smaller and smaller pieces but do not completely disappear for a long time.

Each year over six trillion cigarettes are manufactured globally. Approximately 99% have a filter tip. Filters are often thrown on streets where stormwater runoff sweeps them into rivers and then out to sea, where they can release chemicals including nicotine, benzene, and cadmium.

There are several options available to reduce the environmental impact of cigarette-butt waste, according to Thomas Novotny, an epidemiologist at San Diego State University, in a 2009 study. These options include developing biodegradable filters, increasing fines and penalties for littering, requiring money deposits on filter use, increasing availability of receptacles, and expanded public education.

Too often smokers don't recognize cigarette butts as litter. California has attempted to change that by specifically designating butts as litter and imposing a fine of \$250-to-\$1,000 for their improper disposal. A court can also require the convicted litterer to pick up trash for no less than 12 hours.

Many states and communities have attempted to head off this type of litter in part by passing laws and ordinances prohibiting smoking in parks and on beaches. Maine prohibits smoking in all state parks and beaches. Many municipalities have prohibited smoking in parks, while others have prohibited smoking on beaches.

## 10 things you can do for trash-free seas

1. CAN IT. Use a trash can with lid.
2. TAP IT. Drink tap water in a reusable bottle.
3. STOW IT. Be a green boater.
4. BUTT IN. Write your legislator asking for policies that address ocean trash.
5. REMOVE IT. Join volunteer cleanups.
6. BUTT OUT. Use an ashtray so cigarette butts don't reach water.
7. RECYCLE IT. Most plastic materials can be recycled.
8. REUSE IT. Use reusable shopping bags, coffee mugs, and picnic supplies.
9. BUY LESS. Buy less to reduce the amount of plastic reaching the ocean.
10. REINVENT IT. Send emails to companies asking them to reduce packaging and create new ocean-friendly materials.

SOURCE: OCEAN CONSERVANCY



George Leonard, chief scientist at the Ocean Conservancy in Santa Cruz, California, notes a decline in the number of cigarette butts recorded from 2001-2003 to 2011-2013 as part of the U.S. effort in the International Coastal Cleanup, although significantly more U.S. volunteers were involved in the later period. Globally, larger numbers of volunteers are recording larger volumes of butts—nearly a 50% increase from 2001-2003 to 2011-2013.

The Ocean Conservancy has received a grant from the National Oceanic and Atmospheric Administration to dig deeper into the U.S. cleanup data. For instance, why are there declining number of cigarette butts picked up? One hypothesis is that fewer Americans are smoking, so there are fewer cigarette butts on beaches. Or perhaps overwhelmed



**81,089 COLLECTED.** Marty Morganello of the Surfrider Foundation, Charleston chapter, empties a receptacle for cigarette butts at Folly Beach. Cigarette butts comprised more than half of all marine-debris items collected during the 2013 Beach Sweep/River Sweep.

PHOTO/GRACE BEAHM

volunteers are underestimating the number of cigarette butts they pick up. Another hypothesis is that frequent, local cleanups are gathering litter, so there's less trash for the annual cleanups.

Marty Morganello is the blue-water taskforce coordinator for the Surfrider Foundation, Charleston chapter, managing efforts of about

300 local volunteers, some of whom do regular beach cleanups.

"No matter how many sweep cleanups you do," he says, "the volume of butts on the beach seems never-ending. We're trying to educate people that when you drop your cigarette butts on the street, that litter washes into the storm drains and it affects the water and the beach." 🐦



## Reading and Websites



Algalita Marine Research Institute.  
[www.algalita.org](http://www.algalita.org)

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International Pellet Watch.  
[www.pelletwatch.org](http://www.pelletwatch.org)

Marine Debris Solutions.  
[www.marinedebrissolutions.com](http://www.marinedebrissolutions.com)

National Oceanic and Atmospheric Administration Marine Debris Program.  
[www.marinedebris.noaa.gov](http://www.marinedebris.noaa.gov)

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Rochman, Chelsea M. "Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress," *Scientific Reports*, November 21, 2013.

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Southeast Atlantic Marine Debris Initiative.  
[www.sea-mdi.engr.uga.edu](http://www.sea-mdi.engr.uga.edu)

Woods Hole Oceanographic Institution.  
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Zettler, Eric R. and others, "Life in the 'Plastisphere': Microbial Communities on Plastic Marine Debris," *Environmental Science & Technology*, June 7, 2013.

# NEWS & NOTES

## New insights on marketable clams

Lowcountry clam farmers can benefit from a recent study demonstrating the effects of planting time on growth and survival of hard clams.

The S.C. Sea Grant Extension Program, in partnership with two beginning clam farmers, planted clam seed in the fall of 2011 and spring of 2012 at sites in Beaufort and Isle of Palms. Clam seed, averaging 12-to-15mm in size, were planted in soft mesh bags which were then staked to the sea bottom. Each bag was stocked with a thousand clams.

During the grow-out period, clams bury into the muddy bottom, relying on the mesh bag for protection from predators. They extend their siphon—a tube-like structure—to the water's surface to feed on phytoplankton.

A clam typically takes two years to reach harvest size. The Beaufort demonstration site was harvested in December 2013 and the Isle of Palms site was harvested in May 2014.

Established markets exist for various sizes of clams. The names littleneck, cherrystone, top neck, and chowder refer to the size of the clam, from smallest to largest.

Results from the grow-out site at Isle of Palms indicate that by varying planting time farmers can offer a variety of sizes available for market at the same time.

"We expected that an extra six months in the water would make a difference in the size of the clams at harvest," says Julie Davis, the Consortium's living marine resources extension specialist. "The longer a clam is in the water, the bigger it would grow, which is what we saw at the Isle of Palms site."

But that was not the case at the demonstration site in Beaufort. Despite better survival rates there than at Isle of Palms, beginning farmers suspect site selection might have been the reason for slower growth of clams. "This highlights the importance of careful site selection," says Davis.

This study was funded through the National Sea Grant Aquaculture Extension and Technology Transfer program. ♡

## Accountant/fiscal analyst joins Consortium

Michele M. Neff was recently hired as an accountant/fiscal analyst at the S.C. Sea Grant Consortium. Her job duties include grants accounting and management, budget analysis, and revenue and expense report-

ing. She also will serve as the agency's benefits coordinator, recruiting manager, and assist with other human resources activities.

Michele came to the Consortium from Roper Saint Francis Health Care, where she was a senior reimbursement analyst. She earned a B.S. in business administration-accounting from Montclair State University in Upper Montclair, N.J., and a human-resources certificate from Penn State University. ♡



**Michele Neff**  
PHOTO/SUSAN FERRIS HILL/S.C. SEA GRANT CONSORTIUM



**Julie Davis, living marine resources extension specialist, and Jack Whetstone, aquaculture extension specialist, worked with a commercial clam farmer to assess results of clam seed planted at an Isle of Palms site.**

PHOTO/SUSAN FERRIS HILL/S.C. SEA GRANT CONSORTIUM



# NEWS & NOTES



Site captains Brett Champion and Hillary Repik (back row) and volunteers pause for a photo near debris collected in and around Shem Creek in Mt. Pleasant during the 2013 Beach Sweep/River Sweep.

PHOTO/SUSAN FERRIS HILL/S.C. SEA GRANT CONSORTIUM

## Litter cleanup volunteers needed

Beach Sweep/River Sweep—South Carolina's largest one-day cleanup—is scheduled for Saturday, September 20, 2014. Part of the Ocean Conservancy's International Coastal Cleanup, the Sweep is organized by the S.C. Sea Grant Consortium in partnership with the S.C. Department of Natural Resources.

Last year, over 5,400 volunteers statewide removed over 34 tons of debris and covered 272 miles of beaches, marshes, and waterways, but there is still more work to be done.

A list of coastal site captains and areas covered is available at [www.scseagrants.org/content/?cid=49](http://www.scseagrants.org/content/?cid=49). Simply choose a site and contact the site captain directly to let them know you'd like to join their team. If you're interested in cleaning a needy area that is not listed, please contact Susan Ferris Hill, coastal

coordinator, at (843) 953-2092 or [susan.ferris.hill@scseagrants.org](mailto:susan.ferris.hill@scseagrants.org). Volunteers who want to help inland may contact Bill Marshall at (803) 734-9096 or [marshallb@dnr.sc.gov](mailto:marshallb@dnr.sc.gov). ♡

## Coastal Heritage wins prestigious awards

The *Coastal Heritage* team has been recognized with six awards over the past year:

- 2013-2014 Distinguished Award and Best of Show Award from the Society for Technical Communication (STC) – Carolina Chapter in the Technical Publications competition. The rigorous judging process is based on content and organization, copyediting, visual design, and creativity.
- 2013-2014 Award of Excellence from STC's International Summit Awards competition.
- First Place in the Writer's Portfolio

category from the National Association of Government Communicators 2014 Blue Pencil and Gold Screen Awards. This international competition salutes superior communications efforts of government agencies and recognizes the people who create the products.

- Gold Award for Magazines and Periodicals in the 2014 Critique and Awards competition from the Association for Communication Excellence (ACE). This international competition recognizes the work of ACE members who have done an outstanding job.



- 2014 APEX Award of Excellence in the Magazines and Journals category. APEX is an international competition that recognizes outstanding publications in the areas of editorial content, graphic design, and success in achieving overall communications effectiveness and excellence.

Current and back issues of *Coastal Heritage* are available on the Consortium's website at [www.scseagrants.org/products](http://www.scseagrants.org/products). ♡



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# EBBS & FLOWS

## 26<sup>th</sup> Annual Beach Sweep/River Sweep

*Statewide, South Carolina  
September 20, 2014*

Join S.C. Sea Grant Consortium and S.C. Department of Natural Resources for the Beach Sweep/River Sweep litter cleanup on September 20, 2014. Last year, over 5,400 volunteers removed 34 tons of debris from beaches, marshes, and waterways.

To volunteer on the coast, contact Susan Ferris Hill at [susan.ferris.hill@scseagrant.org](mailto:susan.ferris.hill@scseagrant.org) or (843) 953-2092. To volunteer inland, contact Bill Marshall at [marshallb@dnr.sc.gov](mailto:marshallb@dnr.sc.gov) or (803) 734-9096.

## 2014 S.C. Water Resources Conference

*Columbia, South Carolina  
October 15-16, 2014*

This conference will bring together academic, private, and public sectors to discuss water policies, research projects, and water management in order to meet the challenge of providing water resources to sustain and grow South Carolina's economy while preserving its natural resources.

For more information, visit [www.scwaterconference.org](http://www.scwaterconference.org) or contact Dawn Anticole White at [dawnw@clermson.edu](mailto:dawnw@clermson.edu) or (864) 656-2618.

## 16<sup>th</sup> International Conference on Shellfish Restoration

*Charleston, South Carolina  
December 10-13, 2014*

The International Conference on Shellfish Restoration (ICSR) will address current challenges and opportunities for shellfish restoration worldwide, emphasizing the role of community stewardship, public awareness, and education.

ICSR'14 will focus on recent changes in our environmental, economic, and political world.

Visit [www.scseagrant.org/icsr](http://www.scseagrant.org/icsr) for more information.

**Subscriptions are free upon request by contacting: [Annette.Dunmeyer@scseagrant.org](mailto:Annette.Dunmeyer@scseagrant.org)**

**ATTENTION SCHOOL TEACHERS!** The S.C. Sea Grant Consortium has designed supplemental classroom resources for this and past issues of *Coastal Heritage* magazine. *Coastal Heritage Curriculum Connection*, written for K-12 educators and their students, is aligned with the South Carolina state standards for the appropriate grade levels. Includes standards-based inquiry questions to lead students through explorations of the topic discussed. *Curriculum Connection* is available online at [www.scseagrant.org/education](http://www.scseagrant.org/education).